Field Test Program for Long-Term Operation of a COHPAC System for Removing Mercury from Coal-Fired Flue Gas

Quarterly Technical Report
Reporting Period: July 1, 2003 – September 30, 2003

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DISCLAIMER

ABSTRACT

With the Nation's coal-burning utilities facing the possibility of tighter controls on mercury pollutants, the U.S. Department of Energy is funding projects that could offer power plant operators better ways to reduce these emissions at much lower costs. Sorbent injection technology represents one of the simplest and most mature approaches to controlling mercury emissions from coal-fired boilers. It involves injecting a solid material such as powdered activated carbon into the flue gas. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface. The sorbent with the mercury attached is then collected by the existing particle control device along with the other solid material, primarily fly ash.

During 2001, ADA Environmental Solutions (ADA-ES) conducted a full-scale demonstration of sorbent-based mercury control technology at the Alabama Power E.C. Gaston Station (Wilsonville, AL). This unit burns a low-sulfur bituminous coal and uses a hot-side electrostatic precipitator (ESP) in combination with a Compact Hybrid Particulate Collector (COHPAC™) baghouse to collect fly ash. The majority of the fly ash is collected in the ESP with the residual being collected in the COHPAC baghouse. Activated carbon was injected between the ESP and COHPAC units to collect the mercury.

Short-term mercury removal levels in excess of 90% were achieved using the COHPAC unit. The test also showed that activated carbon was effective in removing both forms of mercury– elemental and oxidized. However, a great deal of additional testing is required to further characterize the capabilities and limitations of this technology relative to use with baghouse systems such as COHPAC. It is important to determine performance over an extended period of time to fully assess all operational parameters.

The project described in this report focuses on fully demonstrating sorbent injection technology at a coal-fired power generating plant that is equipped with a COHPAC system. The overall objective is to evaluate the long-term effects of sorbent injection on mercury capture and COHPAC performance. The work is being done on one-half of the gas stream at Alabama Power Company's Plant Gaston Unit 3 (nominally 135 MW). Data from the testing will be used to determine:

1. If sorbent injection into a high air-to-cloth ratio baghouse is a viable, long-term approach for mercury control; and
2. Design criteria and costs for new baghouse/sorbent injection systems that will use a similar, polishing baghouse (TOXECON™) approach.

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LIST OF GRAPHICAL MATERIALS

There are no graphical materials included in this report.

EXECUTIVE SUMMARY

ADA-ES began work on a Cooperative Agreement with the Department of Energy in September 2002 to fully evaluate Activated Carbon Injection (ACI) in conjunction with a high-ratio baghouse (COHPAC™) for mercury control. The work is being conducted at Alabama Power Company's Plant Gaston. During the two-year project, a powdered ACI system will be installed and tested at the plant for a continuous one-year period. ADA-ES' responsibilities for managing the project include engineering, testing, economic analysis, and information transfer functions.

During the fifth reporting quarter, July through September 2003, progress on the project was made in the following areas:

- Restarted carbon injection with a new carbon injection control scheme.
    - There have now been two optimization periods in the original bag test period and we will refer to them separately as:
        - Optimization Period 1 (April 21 – May 27)
        - Optimization Period 2 (June 26 – July 18)
- Began long-term testing on original bags (July 19 – present)
- Injected activated carbon continuously using inlet loading as a feed-forward signal to control the carbon injection rate.
- Developed spreadsheets to monitor and analyze ESP performance.
- Performed Q/A on new fabric and bags. Bags arrived on-site September 10.
- Measured inlet and outlet vapor-phase mercury continuously.
- Periodically measured LOI of hopper ash samples.
- Prepared and presented summary of test results at DOE/NETL's Mercury Control Technology R&D Program Review Meeting in Pittsburgh, PA, on August 12 and at Air Quality IV on September 24 in Washington, DC.

INTRODUCTION

Cooperative Agreement No. DE-FC26-02NT41591 was awarded to ADA-ES to demonstrate Activated Carbon Injection (ACI) technology on a coal-fired boiler equipped with a COHPAC baghouse. Under the contract, ADA-ES is working in partnership with DOE/NETL, Alabama Power, and EPRI.

A detailed topical report will be prepared at the end of the one-year test period. Quarterly reports will be used to provide project overviews and technology transfer information.

Team Members

Duke Power joined the project as a contributing member during this reporting period. This program is made possible by significant cost-share support from the following companies:

- EPRI
- Southern Company and Alabama Power Company
- Hamon Research-Cottrell, Inc.
- Allegheny Power
- Ontario Power Generation
- TVA
- Duke Power
- Arch Coal, Inc.
- ADA-ES, Inc.

A group of highly qualified individuals and companies was assembled to implement this program. Project team members include:

- ADA-ES, Inc.
- Southern Research Institute
- Grubb Filtration Testing Services, Inc.
- Reaction Engineering International

EXPERIMENTAL

Activated Carbon Injection Equipment

The activated carbon injection equipment was installed, field-tested, and continues to operate.

Mercury Analyzer

The mercury analyzer is operating and measuring total vapor-phase mercury at the inlet and outlet of the COHPAC baghouse.

A full equipment description can be found in DOE Report No. 41591R03.

RESULTS AND DISCUSSION

Significant progress was made during this reporting period to meet the overall objective of demonstrating long-term performance of carbon injection for mercury control. The original test plan was adapted to the current operating conditions at the host site. These changes were documented in the previous quarterly report, but primarily consisted of extending the baseline and optimization tests and modifying the injection scheme. This report documents activities and presents results from the second optimization period and the beginning of the long-term test period. An update on ash and coal data recently received from earlier test periods is also presented.

Optimization Period 2 (June 26 – July 18)

Following a second baseline test, carbon injection was again started on June 26 at an injection concentration of 0.35 lbs/MMacf (10 lbs/h). The system was set in load-following mode, where carbon injection rate varied between nominally 5 and 10 lbs/h depending on boiler load conditions. On July 1 and 2, a new carbon injection control program was installed into the system PLC. In this second optimization period, the performance goals were to:

- Inject activated carbon at a rate capable of maintaining mercury removal at or above 80%;
- Implement the capability to automatically either lower or stop carbon injection when inlet mass loading concentrations were causing the baghouse to be at or near continuous cleaning; and
- Continue investigating the cause of the higher than historical COHPAC inlet mass loading and cleaning frequency.

Ash and Coal Samples

To help troubleshoot and understand COHPAC performance, a Hot Foil LOI analyzer was leased from FERCO. This analyzer measures the Loss On Ignition (LOI) of the ash by heating a sample until the remaining combustible material is burned off. This material is mostly unburned carbon. These measurements are made on-site on ash samples collected from the hot-side ESP, A-side COHPAC, and B-side COHPAC hoppers. The analyzer is located in the site-trailer. A summary of the results is presented in Table 1.

- LOI of A- and B-side hopper ash was similar when carbon was injected at a maximum of 0.35 lbs/MMacf (10 lbs/h). The average values were 17.4 and 17.6%. This is higher than LOI measured in the Phase I tests, where baseline hopper ash had an LOI of 11%.

- LOI was lower in the ESP ash than COHPAC ash, with an LOI of less than 13%. It is not unusual to see the percentage of carbon increase as you go through, or in this case out of, the ESP. Carbon particles have very low resistivity and are easily reentrained to the next field. Higher LOI and/or the characteristics of the LOI may be contributing to the current, poorer ESP collection performance. However, complicating this issue is the fact that sometimes LOI particles are large and can fall out in the front hoppers.
- In Phase I, the ESP hopper ash was nominally 7% and the COHPAC ash was 11%.
- When the maximum injection concentration was raised to nominally 0.52 lbs/MMacf (14–16 lbs/h), the LOI of the B-side ash was consistently higher than that of the A-side ash. During the same period, LOI of the A-side ash decreased slightly. The one measurement of the ESP ash showed no significant change during this period.
- Based on a carbon injection concentration of 0.52 lbs/MMacf and a flowrate of 500,000 acfm, the additional inlet loading from activated carbon is nominally 0.0036 gr/acf. With an average baseline inlet mass loading of 0.054 gr/acf, one would predict an increase in carbon of about 7%.

Table 1. LOI measurements on Unit 3 COHPAC and ESP hopper ash.

Date	A-Side (%)	B-Side (%)[a]	ESP (%)	Max Carbon Injection Rate (lbs/h)
7/1/03	16.2	15.2	11.3	10
7/2/03	15.5	18.3		10
7/3/03	20.2	18.5		10
7/7/03	20.0	17.6	13.8	10
7/8/03	15.3	18.4		10 and14
Average	**17.4**	**17.6**	**12.6**	
7/9/03	17.2	21.0		14
7/10/03	15.3	22.9		14
7/11/03	15.6	20.3		14
7/14/03	15.1	18.8	13.1	14
Average	**15.8**	**20.8**	**13.1**	
7/15/03	13.8	18.7		16
7/16/03	15.0	22.8		16
7/17/03	14.8	21.7		16
7/18/03	15.5	12.7		16
Average	**14.8**	**19.0**		

a. B-side has carbon injection

Carbon Injection System

With the help of Ray Wilson, a Southern Company contractor who both programmed and installed the necessary electronic modules, a 4-20 mA signal that is proportional to inlet mass loading into Unit 3B COHPAC was made available from the COHPAC computer. The mass loading measurement is made with a BHA particle analyzer installed upstream of the carbon injection lances (i.e., baseline loading conditions). The signal was then routed to the control panel located at the base of the silo. Activities necessary to complete this conversion included:

- Route a shielded signal wire from Unit 3 control room to the control panel located at the base of the silo.
- Install and connect a 24V power supply inside the control panel to power the 4-20 mA signal.
- Calibrate the analog signal coming into the PLC.
- Revise the control program of the activated carbon injection system to adjust sorbent feedrate based on inlet mass loading in the COHPAC baghouse. This program has the ability for three different carbon injection rates based on three ranges of inlet loading. The initial set points are listed in Table 2.
- The system was operated in this mode since July 1.

Table 2. Initial Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Carbon Injection Rate (lbs/h)
<0.1	10
<0.2	10
>0.2	0

The injection system was shut down from July 3 through 7 to troubleshoot problems with the load sensors.

Mercury S-CEM Measurements

Vapor-phase total mercury was measured at the inlet and outlet of 3B COHPAC throughout this period. One instrument is used to measure from both locations, alternating between the two. Figure 1 presents inlet and outlet mercury concentrations corrected to 3% oxygen, removal efficiency, carbon injection rate, and B-side ash LOI.

- With carbon injection in the load- and inlet load-following modes, outlet mercury concentrations were maintained below nominally 4 $\mu g/Nm^3$. Except for two brief periods when mercury removal decreased to 76%, mercury removal varied between 80 and 98%. Typical removal efficiency during this period was about 89%, with a maximum injection concentration of 0.52 lbs/MMacf (16 lbs/h).
- Figure 1 also includes data from the end of the previous baseline period. The solid vertical line on June 26 represents the start of carbon injection. This is included to show the large variation in outlet mercury and removal efficiency without carbon injection and the relatively consistent removal efficiency once carbon injection was started.
- We are obtaining high, consistent mercury removal at relatively low carbon injection concentrations. Table 3 presents a comparison of long-term performance results and operating parameters between the Phase I and Phase II tests. This table shows that there are significant differences in all of the primary parameters: carbon injection concentration, average Hg removal, variation in Hg removal, baseline ash LOI, baseline Hg removal, and baseline inlet mass loading.
    - Average mercury removal is 89% compared to 78%.

- In the current test, mercury removal varies between 76 and 98%. In previous tests there was a much larger variation, between 36 and 90%.
- Baseline ash LOI is higher in these tests, 17% versus 11%.
- Baseline mercury removal is higher, 26% versus 0%.
- Inlet mass loading to COHPAC is higher, 0.054 gr/acf versus <0.01 gr/acf.

- Although this all appears to be good news, it points out the wide range of operating conditions that can affect both baseline and controlled mercury removal. It also shows that systems must be designed to take into account the potential of these wide variations.
- What is contributing to the higher removal? All we can do right now is provide opinions.
  - It appears that there is some synergy between the current conditions and the effectiveness of activated carbon. In other tests, we have seen both the positive and negative impact of HCl and SO_3 in the flue gas on the effectiveness of activated carbon to adsorb mercury. It is possible that the higher LOI and loading is helping in this case by removing some of the competing species.
  - Since we are seeing varying baseline mercury removal, it appears that activated carbon is acting like a trim to the native control capability of the unit.
- The new control logic has allowed us to inject carbon continuously without significantly impacting baghouse performance.

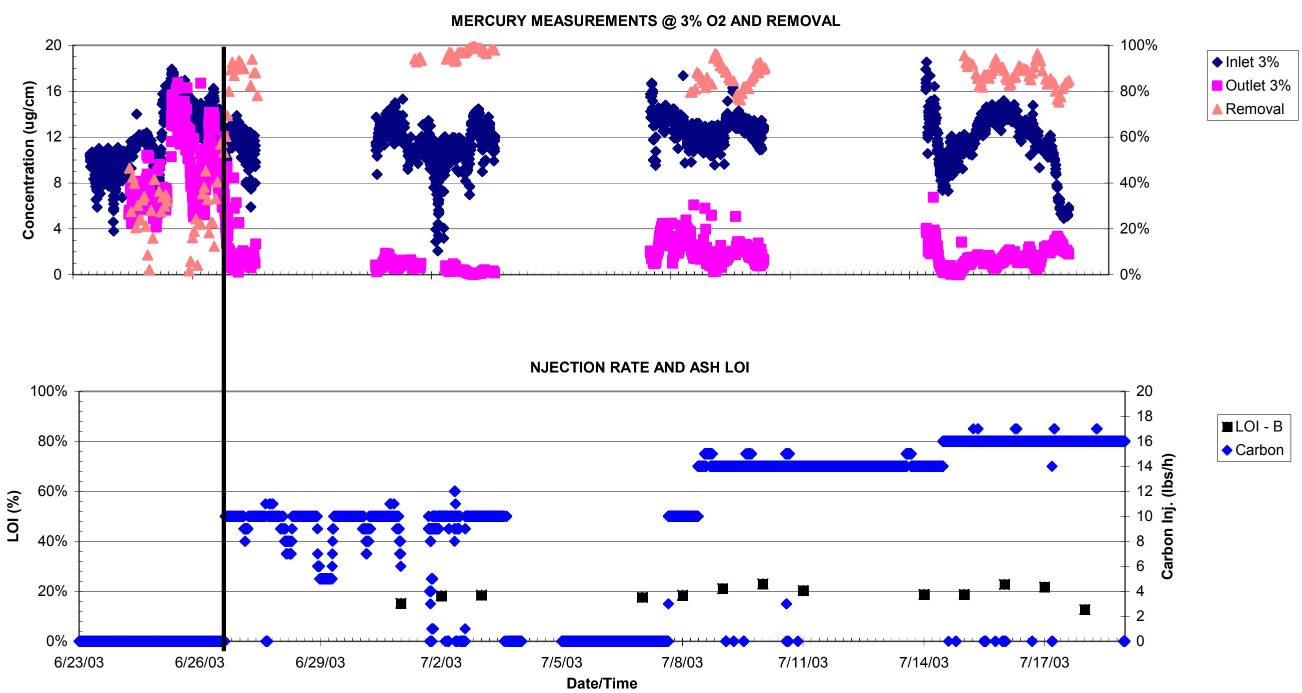

Figure 1. Inlet and outlet mercury concentrations, removal efficiency, carbon injection rate, and ash LOI during Optimization Period 2.

Table 3. Comparison of Phase I (2001) and Phase II (2003) Long-Term Performance and Operating Parameters.

	2001	**2003**
Carbon Injection Concentration	1.5 lbs/MMacf	0.52 lbs/MMacf
Average Hg Removal	78%	89%
Variation	36 – 90%	76 – 98%
Average Baseline LOI	11%	17%
Average Baseline Hg Removal[a]	0	26
Average Baseline Inlet Mass Loading[b]	<0.01 gr/acf	0.054 gr/acf

a. *Average from the Ontario Hydro tests.*
b. *Baseline inlet loading during long-term tests.*
Note: In Phase I, inlet loading was lower during long-term tests than during baseline tests.

COHPAC Performance

The COHPAC baghouses continue to clean at much higher rates than levels seen in either historical averages or the Phase I tests. Figure 2 presents performance data for both A- and B-side baghouses during the current optimization test period. These data include inlet loading, boiler load, and pulse frequency.

- Figure 2 shows that both baghouses have relatively high cleaning frequencies. For this period, the average cleaning frequencies were:
    - 1.9 for A-side
    - 2.3 for B-side
    - A difference of 11%
- Carbon injection has increased the difference between the two baghouses by nominally 6%. In Phase I, the average cleaning frequency increased by nominally a factor of 3 (<0.5 p/b/h versus 1.5 p/b/h). The average cleaning frequencies in Baseline Period 2 were:
    - 1.6 for A-side
    - 1.8 for B-side
    - A difference of 17%
- At this carbon injection rate, there is very little negative impact on COHPAC cleaning frequency.

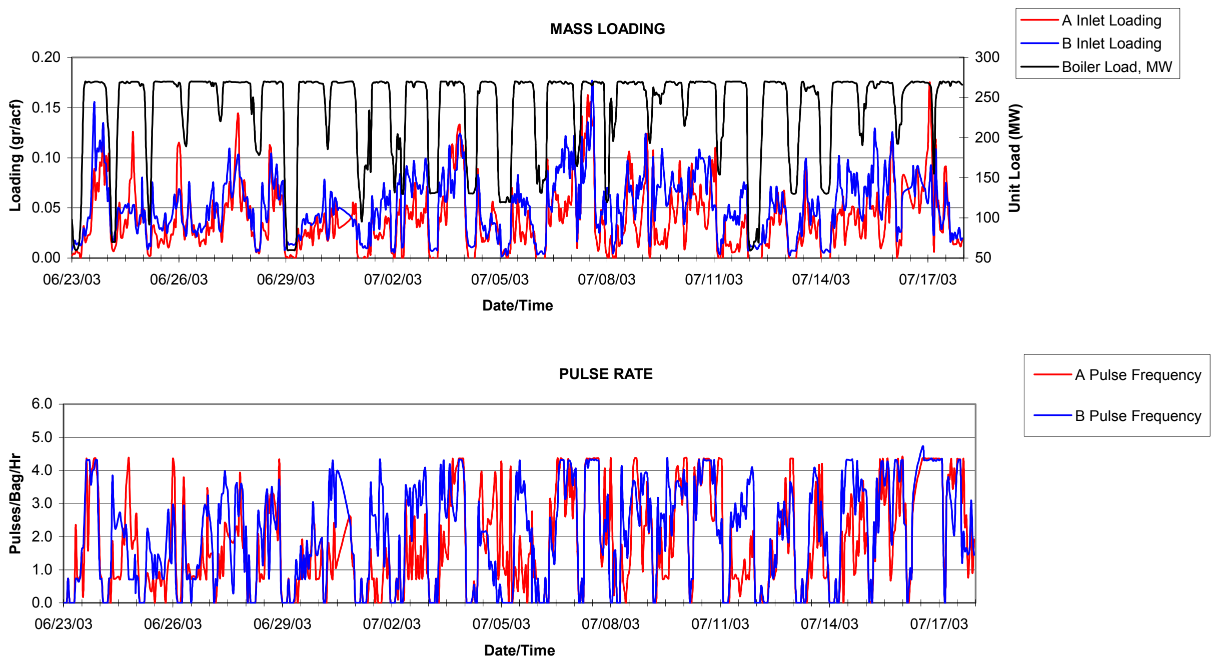

Figure 2. COHPAC performance data for both A- and B-side baghouses during Optimization Period 2.

Ash and Coal Samples
During Optimization Period 2, coal samples were collected daily during the week and ash samples were collected periodically from both the A- and B-side COHPAC hoppers and from the hot-side ESP hopper.

Long-Term Test Original Bags (July 19 – Ongoing)

Between June 26 and July 18, the carbon injection control system was optimized to minimize impact on baghouse cleaning frequency while injecting sufficient carbon to maintain a target removal efficiency of 80%. The long-term test on the original bags officially started on July 19.

Activated Carbon Injection and Mercury Removal Performance
New control logic was programmed into the injection skid PLC to vary carbon injection rate with respect to inlet mass loading. When baseline inlet loading and baghouse cleaning frequency are high, this new control scheme takes advantage of the natural mercury removal and reduces impact on cleaning frequency by lowering or shutting off carbon injection. This program has the ability for three different carbon injection rates based on three ranges of inlet loading. The set points used during this long-term test with the original bags are listed in Table 4. The maximum injection rate is set at either 16 or 20 lbs/h, depending on baghouse conditions and mercury removal. There are times when mercury removal decreases below our target of 80%, which points toward the native ash being less reactive and/or efficient in

removing mercury at the specific conditions. At these conditions, the upper feed rate is increased to 20 lbs/h.

Table 4. Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Inlet Loading (gr/acf)	Injection Concentration (lbs/MMacf)	Carbon Injection Rate (lbs/h)
<0.1	~0.07	0.52 or 0.66	16 or 20
<0.2	~0.14	0.35	10
>0.2	~0.14	0	0

Vapor-phase total mercury is measured at the inlet and outlet of the 3B COHPAC. One S-CEM instrument is used to measure from both locations, alternating between the two. Up until July 21, the mercury analyzer was operating only during weekdays (Monday through Friday). Beginning on July 21, the analyzer was left running, unattended, over the weekends. Although the analyzer was in service, we have had several instances where power fluctuations or plugged chemical feed lines interfered with data collection. A later section will describe recent O&M improvements made to the mercury measurement system.

Inlet and outlet total vapor-phase mercury, calculated mercury removal, carbon injection concentration, and an indication whether the bypass damper was open are presented graphically in Figures 3 – 7 for July 19 through September 30. These figures can be found at the end of this section. Weekly averages were calculated for inlet and outlet mercury concentrations and for mercury removal efficiency and are presented in Table 5. The standard deviation of the average mercury removal efficiency can also be seen in this table. Figure 8 plots daily and weekly averages of inlet and outlet mercury concentrations and mercury removal.

Analysis and Interpretation of Figures 3 – 8 and Table 5:

Carbon Injection System

- The carbon injection system was knocked off line by severe lightning in the area two different times in this reporting period. After investigating the problem, we learned that other users have also experienced failure of electronic boards in the control system from voltage surges during lightning storms. The boards were replaced, but ADA-ES is looking into obtaining these boards from a different supplier.
- The system was off line on August 27 and 28, and from August 31 through September 2. An increase in outlet mercury concentration can be seen on August 27. The August 31 strike also took out the mercury analyzer.

COHPAC Bypass Damper Operation

- Because of high baghouse cleaning frequency and pressure drop, the bypass dampers to the baghouse were partially or fully opened to relieve pressure drop. This occurred both in July and August. The COHPAC computer tracks bypass damper position, but this value is not always accurate. A good example of what happens when the bypass damper is partially opened can be seen in Figure 3. An indication of the bypass damper position is plotted on the lower graph. On July 19 – 21, the bypass damper opened twice. Carbon injection continued because the inlet loading was not above the setpoint to turn it off. Mercury removal decreased because unfiltered flue gas was now mixing with filtered flue gas in the outlet. Mercury removal decreased to about 70%.

- The Ontario Hydro tests that were scheduled for the week of August 25 were postponed because of the need to operate with the bypass dampers open. These tests will now be conducted the week of October 6.

Mercury Concentrations and Removal Efficiencies

- Figure 8 and Table 5 present average mercury concentrations and efficiencies. The average inlet mercury concentration was 13.4 $\mu g/Nm^3$, with daily average concentrations varying between nominally 5.1 to 25.6 $\mu g/Nm^3$. This is about the order of magnitude in variation seen in the Phase I test.
- The average outlet mercury concentration for the same period was 1.9 $\mu g/Nm^3$, with daily average concentrations varying between 0.24 and 6.2 $\mu g/Nm^3$.
- Average mercury removal during the period was 86.1%, with a minimum daily average of 63.5% and a maximum daily average of 98.1%.
- Weekly average mercury concentrations can be seen in Table 5, and these values are also plotted in Figure 8. Our goal for these tests is to maintain mercury removal above 80%. On a weekly basis, this goal was met for 10 of the 11 weeks. During the week of September 14, the average mercury removal fell below 80% to 75.8%, even with carbon injection. Two things could have contributed to this. First, the baghouse was in continuous cleaning, which did not allow much of the activated carbon to build up on the bags. However, there were other periods when the baghouse was cleaning continuously and removal efficiency remained high. The second factor could be variations in the affinity for mercury from the native fly ash. We have seen in this test that a much lower activated carbon injection concentration is required to obtain similar high removal efficiencies seen with previous testing at Gaston. We suspect that the presence of the high carbon ash may be enhancing the performance of the activated carbon–fly ash combination. A change in coal or combustion conditions during one of the weeks may have resulted in a fly ash with a reduced impact on mercury removal and a higher requirement for activated carbon. Without changing injection concentration, the removal efficiencies increased to above 80% after a few days. This period can be clearly seen in Figure 5, which also shows cleaning frequency.
- Table 5 also shows the standard deviation associated with the average removal efficiency numbers. Under current conditions, the standard deviation is as high as 12%, which implies that to maintain mercury removal above 80% we would have to be able to inject more carbon to target greater than 90% removal on average.
- Daily and weekly values are shown graphically in Figure 8. It is encouraging that even though the inlet concentrations are highly variable, the daily and weekly removal efficiencies are fairly steady.
- Mercury removal was below 80% from September 18 through September 22.

Table 5. Average weekly inlet and outlet mercury concentrations, and mercury removal.

Week Starting	Inlet Mercury ($\mu g/m^3$)	Outlet Mercury ($\mu g/m^3$)	Mercury Removal (%)	Standard Deviation
7/20/03	9.2	0.8	91.3%	6.5
7/27/03	11.8	0.8	93.2%	3.6
8/3/03	18.1	1.6	91.2%	4.5
8/10/03	13.0	1.6	87.7%	10.7
8/17/03	14.9	2.0	86.6%	12.0
8/24/03	13.9	2.9	79.1%	6.3
8/31/03	13.2	1.7	87.1%	5.7
9/7/03	13.1	2.3	82.4%	6.3
9/14/03	16.7	3.8	77.2%	10.6
9/21/03	11.8	1.9	83.9%	7.3
9/28/03	11.3	1.1	90.3%	1.6
Overall Average	13.4	1.9	86.1%	

Mercury S-CEM O&M Improvements

The most time-consuming effort associated with operation of the analyzer is with keeping the wet chemistry based conversion/speciation conditioning system functioning. Three changes that were made to the impingers that decreased maintenance time were 1) modifying the impinger design to reduce the number of fittings (which reduces the potential for leaks), 2) moving the feed and waste ports for more efficient mixing, and 3) mounting the impingers on a board for easier handling. A clean set of impingers and feed lines will operate for up to four days before they have to be changed and cleaned.

On a different program, an evaluation of extraction probes was conducted. This test showed that the extraction probe that we are using, which is stainless steel, oxidized mercury as the gas passed through the inertial filter. The tests revealed that the measurement artifact could increase measured oxidized mercury by up to 17%. We are looking into evaluating different extraction probes and calibration system at Gaston.

The mercury detector used at Gaston is a cold vapor atomic absorption spectrometer (CVAAS) coupled with a gold amalgamation system (Au-CVAAS). Several vendors that offer similar, commercial systems are interested in side-by-side comparisons with our analyzer. We are looking into obtaining other detectors and installing them in parallel with our existing detector to compare data, reliability, and operation of the two.

COHPAC and ESP Performance

The high cleaning frequency of the COHPAC baghouses continues to be a concern. Figures 9 and 10 present performance data for A- and B-side baghouses for this reporting period. The top graph shows inlet mass loading and pulse cleaning frequency for B-side, the second graph presents the same data for A-side, and the lower graph shows boiler load and carbon injection concentration into B-side.

Interesting observations from these data include:

- Comparing A- and B-side in Figure 9, the inlet loading and cleaning frequency is lower on A-side, especially from August 3 through August 24. Figure 10 shows an increase in cleaning frequency on A-side in September, with extended periods of continuous cleaning.
- At low load operation in August, the cleaning frequency on both baghouses decreased dramatically.
- Unit 3 appeared to be base loaded at high load for an extended period at the end of September. During this time, both sides had extended periods of continuous cleaning.
- The average cleaning frequencies for this time period and the previous for each side were:
  - A-side = 2.3 p/b/h versus 1.9 p/b/h;
  - B-side = 3.5 p/b/h versus 2.3 p/b/h.
- Cleaning frequency on A-side has increased by about 17% since the last progress update, while B-side has increased by 35%. Remembering that when the baghouse is in a continuous clean the pulse frequency is 4.3 p/b/h, B-side is very close to being in a continuous clean most of the time.
- At the current injection rate, we would expect the carbon to cause a 1 p/b/h increase in cleaning frequency. This would account for the higher cleaning frequency on B- versus A-side.
- The new set of 7-denier, high-permeability (high-perm) bags was delivered to Gaston in September. These bags are scheduled to be installed the week of November 3. A contractor will be hired to remove the original bags and replace them with the high-perm bags. Since this changeout will occur with Unit 3 on-line, we will coordinate with the plant and the final schedule will be to work within the plant's requirements.
- Grubb Filtration Testing Services performed all of the QA and acceptance activities associated with the new bags.
- Prior to removing the original bags, in-situ drag will be measured and bags will be removed for strength testing.

Many groups, including Southern Company, are still investigating ESP performance and its impact on the higher inlet loading to COHPAC. One hurdle in troubleshooting the ESP performance was that there was not access to historical ESP power data. In July, an upgrade to the controls was implemented and these data are now available. ADA-ES assisted Southern Company by putting together spreadsheets to import and analyze the data.

Hamon Research-Cottrell provided two experts to go to the site and observe ESP and baghouse operation. The trip report from the ESP inspection is included in Appendix A. In summary:

- Power levels were extremely low on all fields.
- Resistivity is very low because of high LOI.

- It is suspected that there may be insulator-tracking type problems from high carbon ash on the insulators.

Ash and Coal Samples

Coal samples were collected daily and ash samples were collected periodically from both the A- and B-side COHPAC hoppers, and from the hot-side ESP hopper. LOI of ash samples are measured periodically.

Baseline 1 and Optimization 1 Coal and Ash Results

Coal and ash samples are taken routinely. Samples from the initial baseline period (when Ontario Hydro tests were performed) and from the first optimization period were chosen for analysis. Connie Senior with Reaction Engineering International oversees selection of test samples, coordinates testing with Microbeam Technologies, and analyzes the results. Connie also coordinates requests for ash samples from non-team members. Both Southern Company and DOE have requirements for approval and tracking of the samples.

A copy of the Coal and Ash Sample Report for April and May can be found in Appendix B. Coal tests include Ultimate and Proximate analyses and measurements of mercury and chlorine. Coal mercury levels varied between 0.058 and 0.11 μg/g (dry basis) or an equivalent of 6 and 13 $\mu g/dnm^3$ (at 3% O_2) in the flue gas. In the nearly seven weeks of baseline tests, S-CEM measurements showed mercury levels varied between 7 and 18 $\mu g/dnm^3$.

Ash samples are analyzed for LOI and mercury content. Table 6 summarizes the results from ash samples taken in April and May. April samples were taken during baseline conditions and May samples during the optimization tests with carbon injection. Three things stand out:

1. Average LOI of B-side COHPAC ash was 19.2% at baseline conditions compared to 16.9% with carbon injection. This shows that at the low injection rates, there was no measurable difference in LOI due to carbon injection.
2. Mercury content of the B-side ash was 5.9 μg/g at baseline and 7.6 with carbon injection. These data indicate that mercury is being removed under baseline conditions and that more mercury is being removed during carbon injection. This corresponds well with flue gas measurement results showing baseline mercury removal and increased average mercury removal during carbon injection.
3. The mercury content of the A-side ash is much lower than the B-side during baseline operation. No flue gas mercury measurements were made on the A-side during the ash collection period, but the lower mercury content in the A-side ash indicates that the mercury removal on the A-side was probably much lower than the B-side. The LOI was also lower on the A-side versus the B-side for the April sample shown.

Table 6: Mercury and LOI of Ash Samples from April and May, 2003

ADA-ES #	MTI #	Sampled	Description	Hg, µg/g	LOI, wt%
GAS00203	03-190	4/2/2003	B-side BH	5.38	17.8
GAS00204	03-191	4/2/2003	HESP	0.334	13.6
GAS00205	03-192	4/2/2003	A-side BH	0.241	10.8
GAS00208	03-195	4/3/2003	B-side BH	6.4	21.4
GAS00265	03-199	5/14/2003	A-side BH	0.894	16.5
GAS00266	03-200	5/14/2003	B-side BH	7.61	16.9
GAS00267	03-201	5/14/2003	HESP	0.53	13.7

Recommendations and Schedules

- We plan to continue operating with our current carbon injection logic, mercury measurement scheme, and sample collection schedule for the remainder of this test.
- The first long-term test period is scheduled to end on October 31. New bags will be installed the week of November 3.
- The Ontario Hydro measurements are scheduled for the week of October 6. The test matrix will be similar to the baseline tests:
  - Triplicate Ontario Hydro measurements at the inlet and outlet of U3B COHPAC;
  - Method 29 (multimetals) at the outlet of U3B COHPAC; and
  - HCl measurements at the inlet to U3B COHPAC.
- An on-site team meeting/webcast is scheduled for October 22.

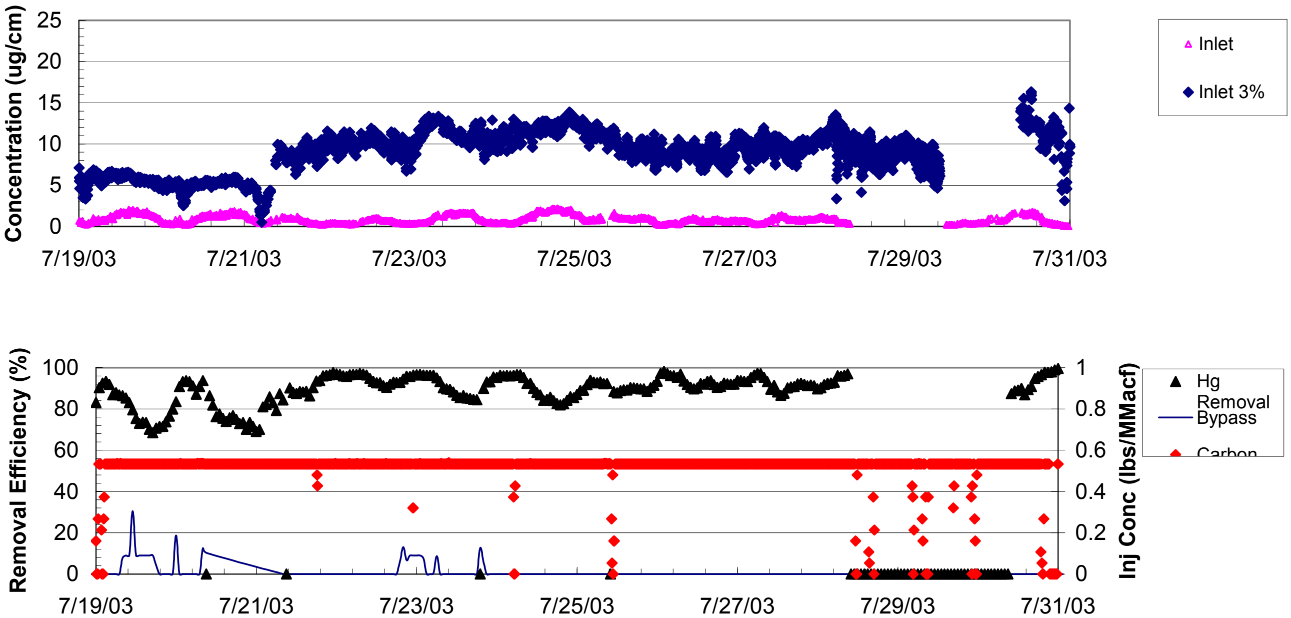

Figure 3. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, and position of bypass damper on Unit 3B COHPAC from July 19 through July 31.

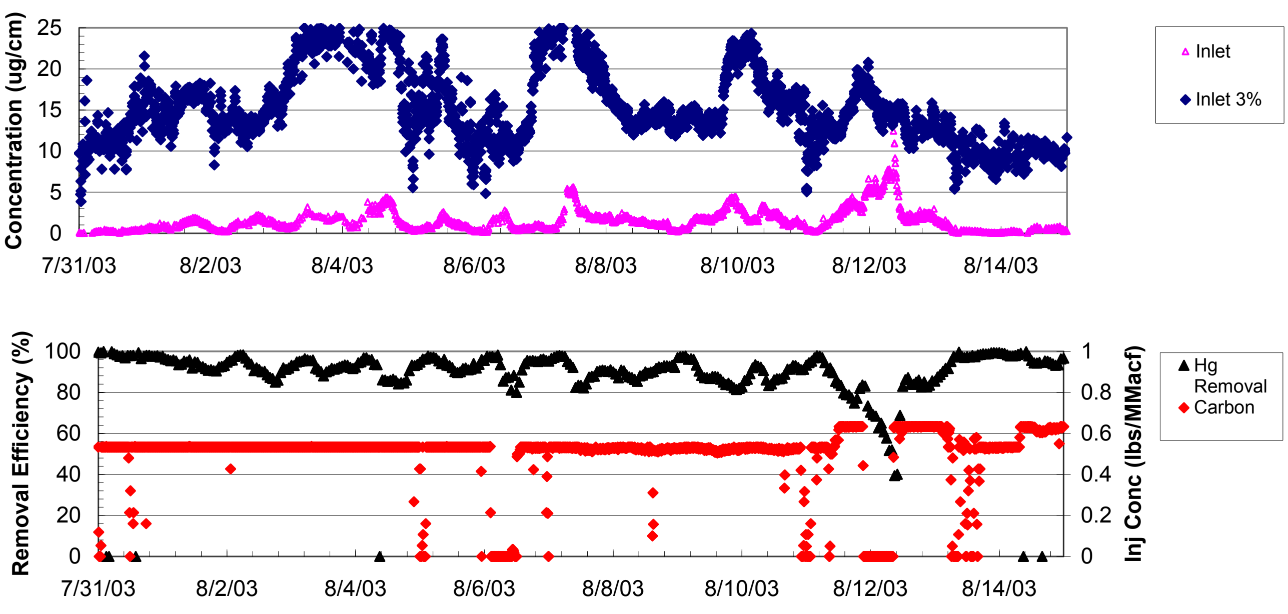

Figure 4. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, and position of bypass damper on Unit 3B COHPAC from July 31 through August 15.

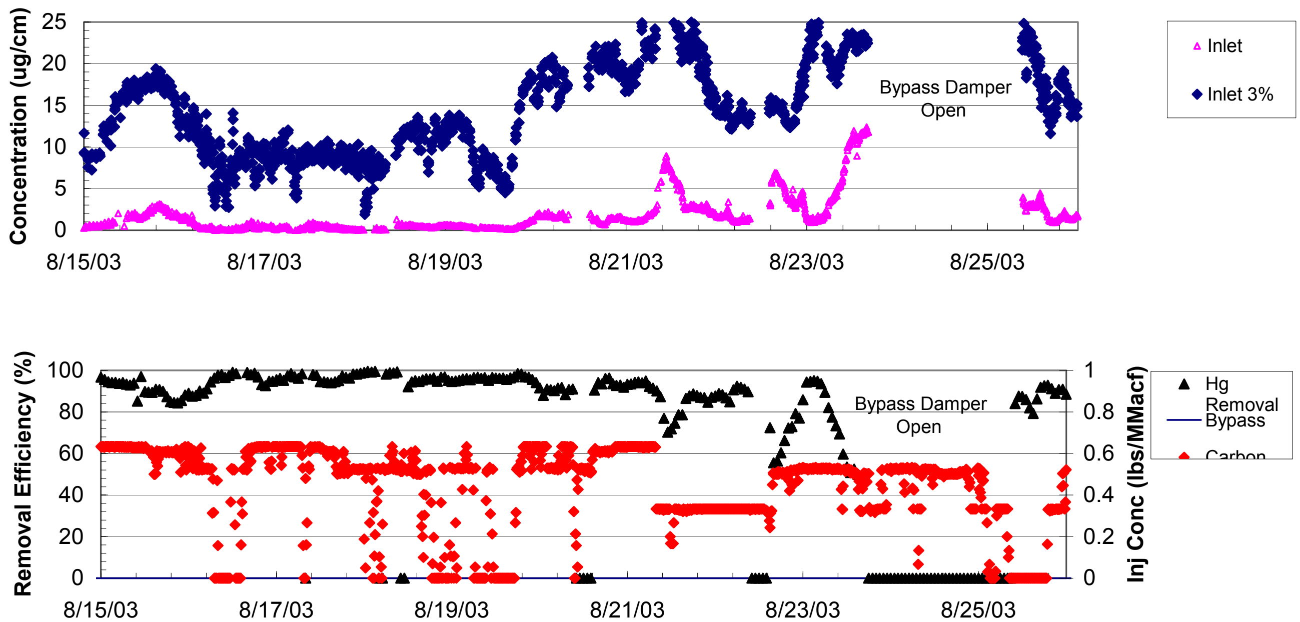

Figure 5. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, and position of bypass damper on Unit 3B COHPAC from August 15 through August 27.

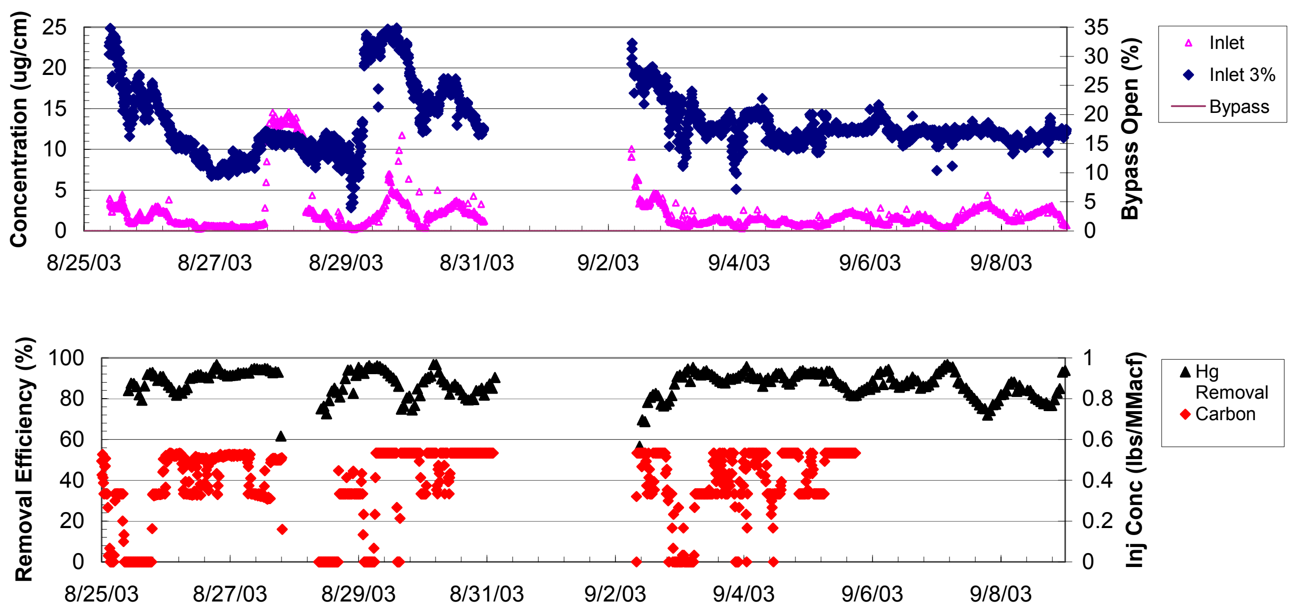

Figure 6. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, and position of bypass damper on Unit 3B COHPAC from August 25 through September 9.

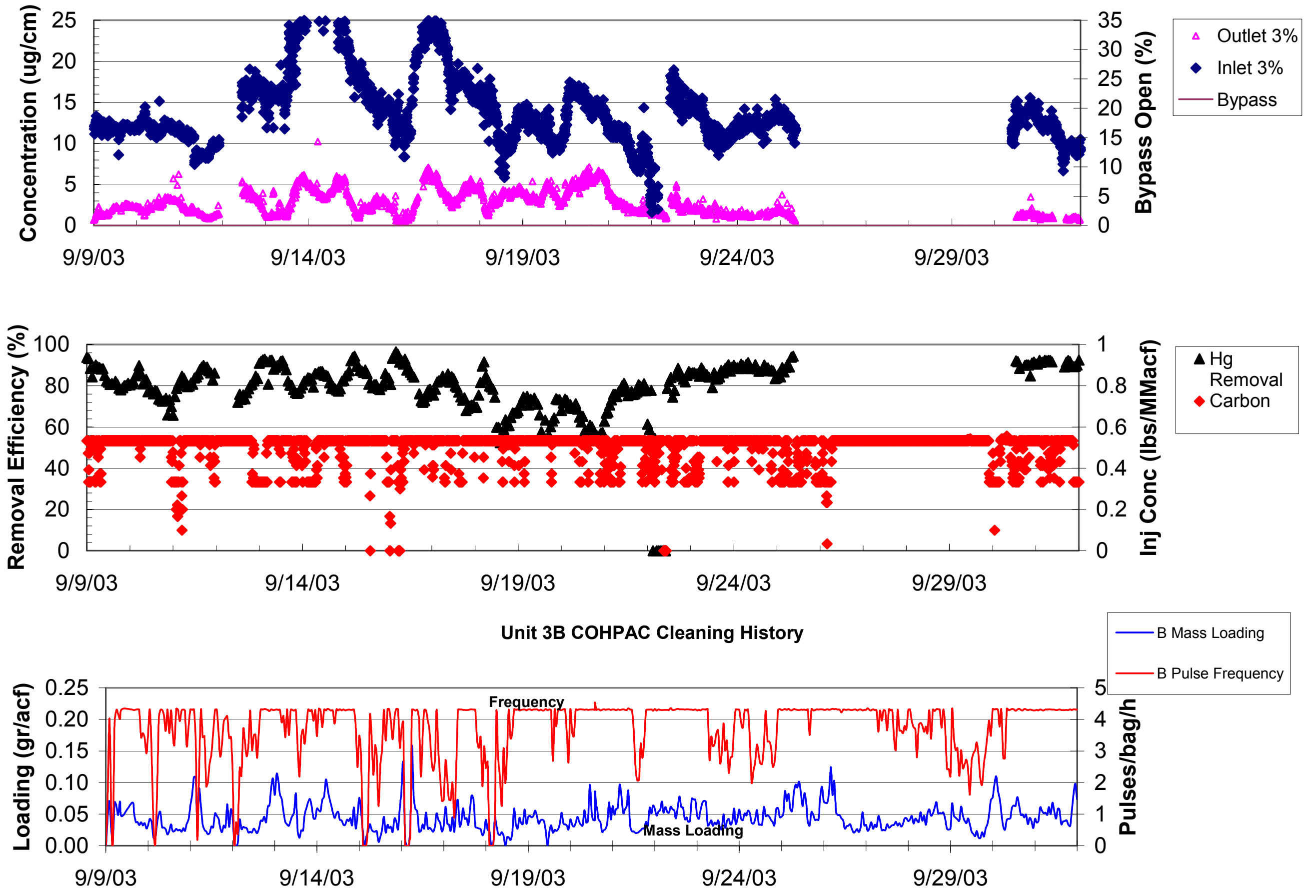

Figure 7. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, position of bypass damper, and COHPAC performance on Unit 3B COHPAC from September 9 through October 1.

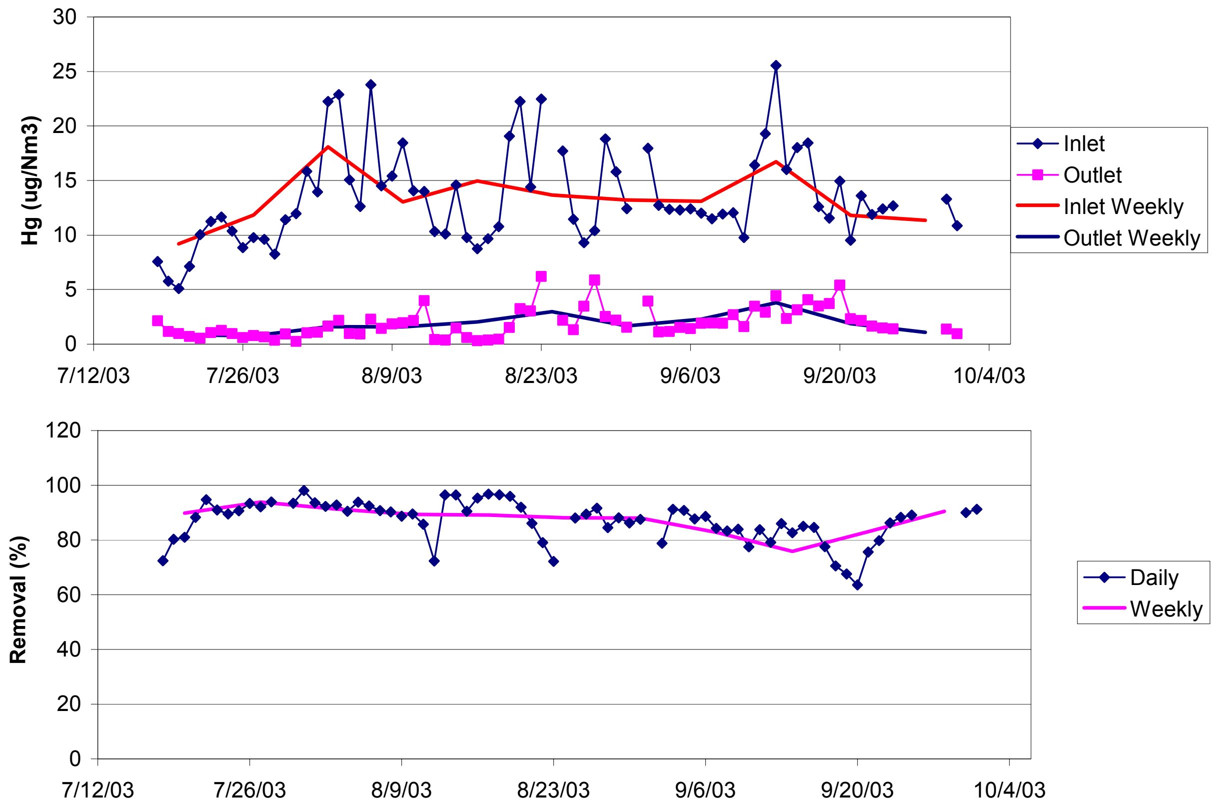

Figure 8. Daily and weekly averages of inlet and outlet mercury concentrations and mercury removal from July 19 through October 1.

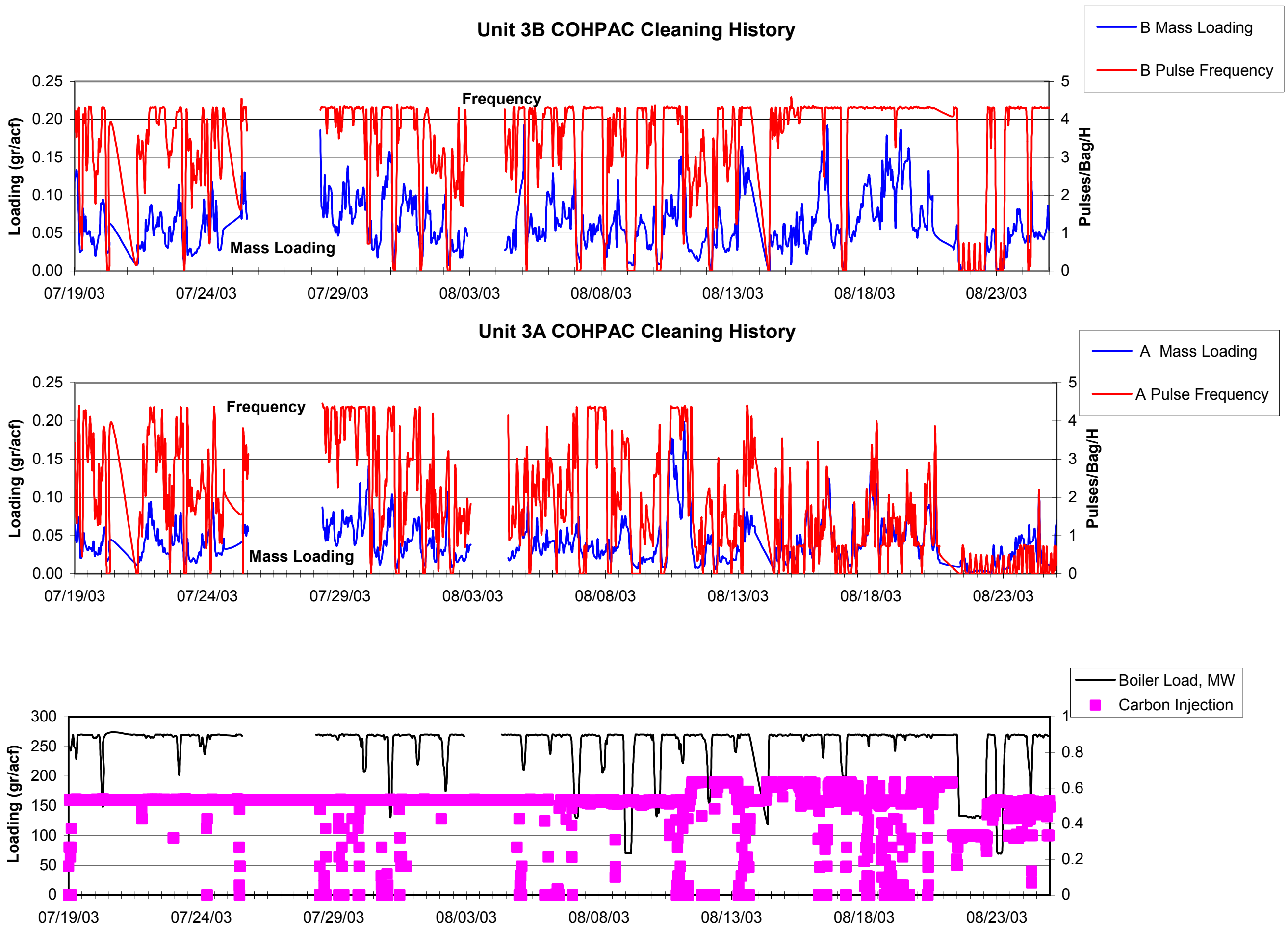

Figure 9. Units 3B and 3A COHPAC performance (cleaning frequency and inlet mass loading), and boiler load and carbon injection concentration from July 19 through August 24.

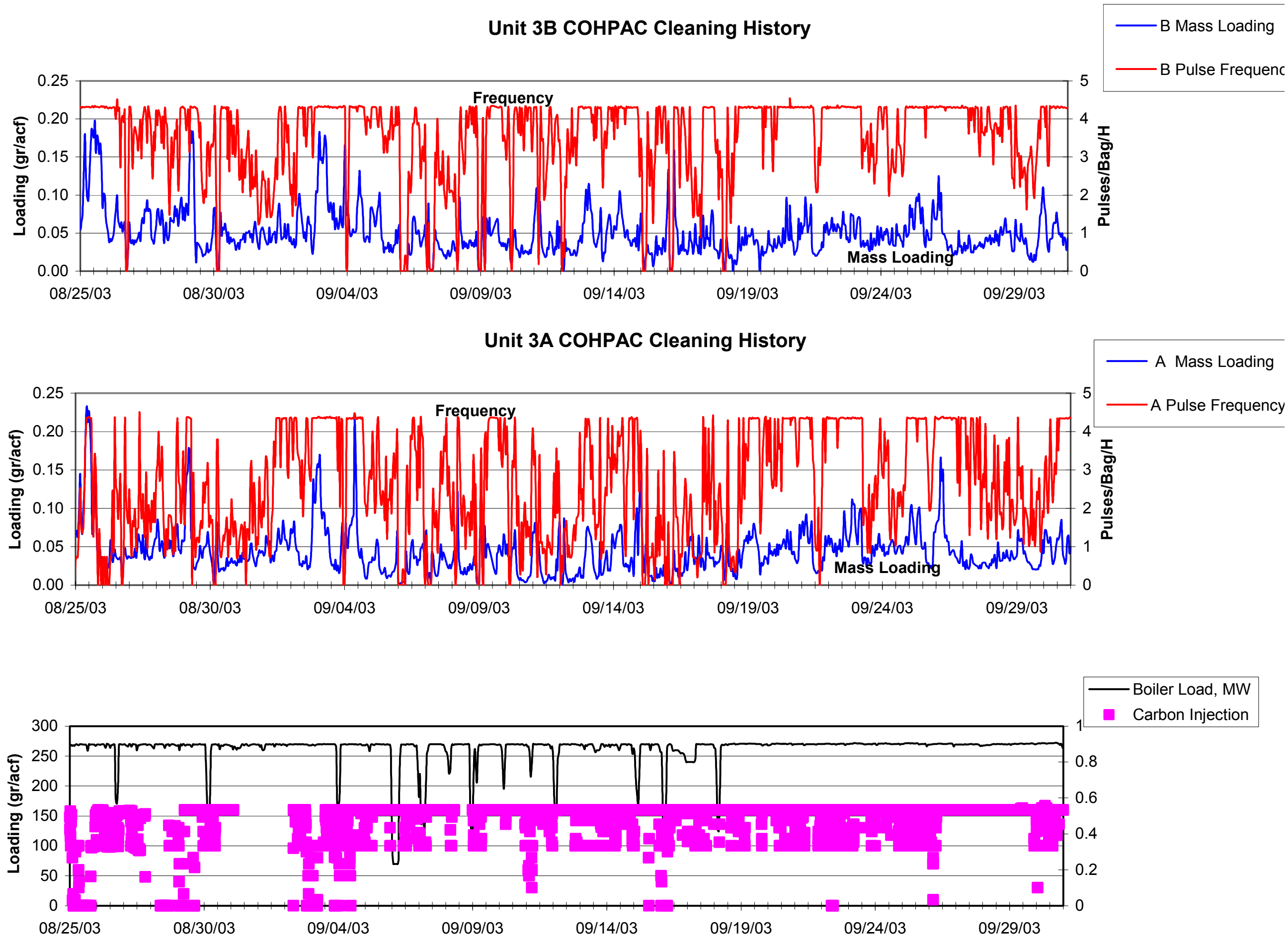

Figure 10. Units 3B and 3A COHPAC performance (cleaning frequency and inlet mass loading), and boiler load and carbon injection concentration from August 25 through October 1.

Appendix A

Hamon Research-Cottrell Trip Report
ESP Inspection October 1, 2003

To: Byron Corina
From: Robert Mastropietro
Date: October 31, 2003
Subject: Southern Companies - Gaston #3 - External Process Study

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Field Notes;

1. A review of the ESP sizing showed a design treatment time of 6.2 seconds. This was a typical ESP sizing for the 1973 time period. This ESP should be able to achieve about 0.1 LB/MMBTU if not in a deteriorated condition.
2. Power levels were extremely low on all fields of the ESP. On October 1, 2003, power densities ranged from 0.08 to 0.51 Watts/FT2 on all fields. This is extremely low. We would consider power densities in the range of 1.0 to 3.0 Watts/FT2 to be representative of good operation. Thus no part of the ESP was operating in good condition. In addition, two chamber fields were out-of-service (not in-series), out of 16 total chamber fields.
3. Predicted emission from taking two chamber fields out of service (not in-series) would be an increase of about 50% in particulate emissions. Thus if we were making 0.1 LB/MMBTU before, we would increase to about 0.15 LB/MMBTU with two chamber fields out. As a side note, if the two fields were in-series, the prediction would be a doubling of the particulate emissions to 0.2 LB/MMBTU.
4. In previous internal discussions on COHPAC, we have always discussed that the upstream ESP must clean down to the 0.4 LB/MMBTU range (I do not know the specifics of this COHPAC design). In general if this is true, and the ESP were operating good, then the increase to 0.15 LB/MMBTU would not be sufficient to cause the continuous cleaning problems observed on the baghouse. This would imply that the present problem with the baghouse cleaning is not just coming from the 2/16th of the ESP out-of-service. The very poor electrical operation of the ESP is also contributing to the higher loadings coming to the baghouse.
5. Resistivity tests were conducted on two fly ash samples from the #3 hoppers. The results are attached. This showed the fly ash to be extremely low in resistivity. This result typically comes from high carbon in the fly ash, coming from the low NOx burner firing. This result clarified several things after my visit. First, all suspicions of the problem being associated with high resistivity coal can be discarded. Instead, other areas of the ESP now become suspect. The primary area of concern now would be the insulators. This high carbon ash, if it coats the insulators, can cause a conductive path to ground. V-I curves conducted at the site showed very low voltages and almost vertical increases in current. This is typical of insulator tracking type problems.
6. High voltage rapper density was installed with two rappers per high voltage frame. This results in 7,128 linear feet of wire per rapper. This is an extremely poor rapping density. This should be improved by adding a center rapper to each bus-section.

RECOMMENDATIONS

1. At the next outage, perform an internal inspection with special attention being paid to the support and stabilizer insulators. We would be looking for tracking. If the problem is in the support insulators, the heating ventilation system should be upgraded. If the problem is in the lower stabilizer insulators (high probability of the problem being in this area), the lower stabilizers should be upgraded to HRC Rigidflex Stabilizer design with 30” insulator.
2. Low resistivity ash is very re-entrainable. It may be that the rappers are rapping too hard at present, because operators were expecting high resistivity ash. The rapping program of the ESP should be tuned for low resistivity, but an opacity meter between the ESP and baghouse is needed to accomplish this task. I do not know if Southern Companies has a temporary opacity probe for this purpose or not? Alternately, we could try to tune rappers based upon baghouse cleaning cycle, but this is a difficult technical approach.
3. Center rappers should be added to each bus section, and rapper anvils cut to isolate rapping energy.
4. T-Rs are slightly over-sized on the inlet field. Future replacements should decrease the inlet T-R sizes down to 1000ma, from the present 1500ma sizing.

FLY ASH RESISTIVITY ANALYSIS

SOUTHERN COMPANIES – GASTON #3

RESULTS

Resistivity tests were conducted on two fly ash samples obtained from the electrostatic precipitator ash handling system. The dust samples were dark grey in color, which is typically due to high fly ash carbon levels. The fly ash appeared to be free flowing and very fine in texture. Laboratory tests were conducted with resistivity chamber gas moisture at 7 % moisture by volume, which is typical of the actual flue gas moisture from oil firing. This moisture value is not sufficient to give appreciable surface conditioning of the dust by condensed water on the dust surface, except at very low gas temperatures.

The results of laboratory testing are shown on the attached plot of resistivity, OHM-CM, vs. temperature, degrees C. The dust resistivity ranged from 1E5 OHM-CM at low and high temperature, to 2E6 OHM-CM at the resistivity peak. The resistivity peak was at about 300F, which is typical. In general, this fly ash was extremely low in resistivity. Electrical operation (i.e. power density levels) of an electrostatic precipitator would typically be positively impacted by this low resistivity fly ash (i.e. we should have high power levels). A relatively small ESP treatment time would be recommended for this easy ash. However, low gas velocities would be recommended to prevent re-entrainment of fly ash.

DEFINITION

Laboratory resistivity (OHM-CM) of a dust is the ratio of the applied electric potential across the dust layer to the induced current density. The value of the resistivity for a dust sample depends upon a number of variables, including dust chemistry, dust porosity, dust temperature, composition of gaseous environment (i.e. gas moisture), magnitude of applied electric field strength, and test procedure.

In working with electrostatic precipitators (ESP), resistivities are encountered in the range from about 1E4 to 1E14 OHM-CM. The optimum value for resistivity is generally considered to be in the range of 1E8 to 1E11 OHM-CM. In this range the dust is conductive enough that charge does not build-up in the collected dust layer and insulate the collecting plates. Additionally the dust does not hold too much charge and is adequately cleaned from the collecting plates by normal rapping. If resistivity is in the range 1E12 to 1E14 OHM-CM, it is considered to be high resistivity dust. This dust is tightly held to the collecting plates, because the dust particles do not easily conduct their charge to ground. This insulates the collecting plates and high ESP sparking levels result (also poor ESP collection efficiencies). Conversely if the dust is low resistivity, 1E4 to 1E7 OHM-CM, the dust easily conducts its charge to the grounded collecting plates. Then there is not residual charge on the dust particles to hold them on the plates. Thus these particles are easily dislodged and re-entrain back into the gas stream. ESP gas velocities are generally designed in the 2.5-3.5 FT/S range, if high carbon particles are to be collected.

PROCEDURE

The tests procedure was in general accordance with IEEE-548, Standard Criteria for the Laboratory Measurement of Fly Ash Resistivity. The apparatus used for the testing is a custom built arrangement utilizing a high temperature oven, a controlled temperature water bath for gas humidity adjustment, a DC power source, and a electrometer for current flow measurement. Resistivity values are calculated from

$\rho = (V/I) \cdot (A/L)$ where

ρ = resistivity, OHM-CM
V = applied voltage, Volts
I = measured current, Amperes
L = Ash thickness, cm
A = current measuring electrode face area, cm^2

The resistivity testing was conducted in ascending temperature order.

Robert A. Mastropietro
Mgr. ESP Technology
Hamon Research-Cottrell
October 6, 2003

Appendix B

Coal and Ash Sample Report: April – May 2003

Date: September 19, 2003

From: Connie Senior

To: Jean Bustard, ADA ES

Re: Coal and Ash samples from Gaston for April, May 2003

Coal and ash samples were taken in April and May 2003 as part of the long-term sorbent injection test program. The coal and ash samples were compared with similar samples obtained during the Phase I testing at Gaston in 2001. Ash samples taken on April 2 and 3 were baseline (no sorbent injection). The ash sample taken on May 14 was during injection of 0.35 lb/MMacf into the B-side of the baghouse.

Table 1 gives the coal analyses from 2003. The coal mercury levels fluctuated from 0.058 to 0.11 µg/g (dry basis) or 6 to 13 µg/dnm^3 (at 3% O_2). This variation is not any larger than the variation observed in the coal samples obtained during the test in 2001, as can be seen by comparing Figures 1 and 2. However, neither sample size is very large.

Table 1. Coal Analyses.

ADA-ES#:	GAS00181	GAS00182	GAS00183	GAS00206	GAS00207	GAS00259	GAS00260	GAS00261
MTI #:	03-187	03-188	03-189	03-193	03-194	03-196	03-197	03-198
Sampled:	3/31/03	4/1/03	4/2/03	4/3/03	4/4/03	5/12/03	5/13/03	5/14/03
Description:	coal belt	coal belt	coal belt	coal belt	coal belt	coal belt	coal belt	coal belt
Ultimate, wt%, As Received:								
Carbon	67.19	68.68	69.15	67.96	68.98	69.61	69.54	65.08
Hydrogen	4.18	4.36	4.59	3.39	4.32	4.30	4.21	4.36
Oxygen (by diff.)	12.14	11.72	11.08	12.74	11.61	10.66	11.43	14.93
Nitrogen	1.38	1.42	1.46	1.43	1.44	1.41	1.43	1.37
Total sulfur	1.52	1.41	1.67	1.66	1.45	1.25	1.16	1.22
Ash	13.59	12.41	12.05	12.82	12.20	12.77	12.23	13.04
Total moisture	6.15	7.07	6.42	6.85	7.04	7.80	8.05	9.43
Heating value, BTU/lb, As Received	12,119	12,044	12,184	12,002	12,092	12,046	12,112	11,875
Hg, µg/g, dry	0.102	0.0584	0.085	0.113	0.0721	0.0674	0.071	0.0774
Cl, µg/g, dry	170	240	210	190	210	160	150	180
Hg, lb/TBTU	7.90	4.51	6.53	8.77	5.54	5.16	5.39	5.90
Hg, µg/dnm^3 (3%O_2)	11.39	6.27	9.00	12.91	7.73	7.08	7.52	8.66

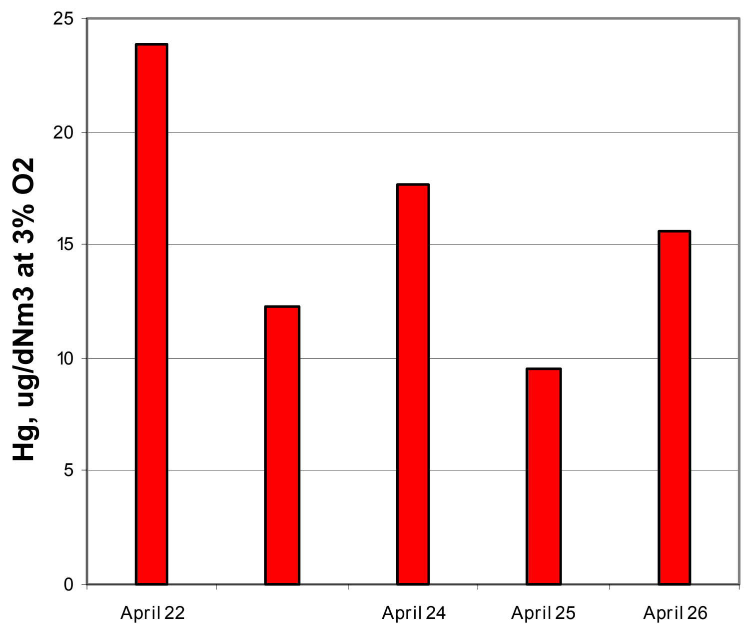

Figure 1. Coal mercury, in terms of µg/dnm^{3}at 3% O_2 for 2001 samples.

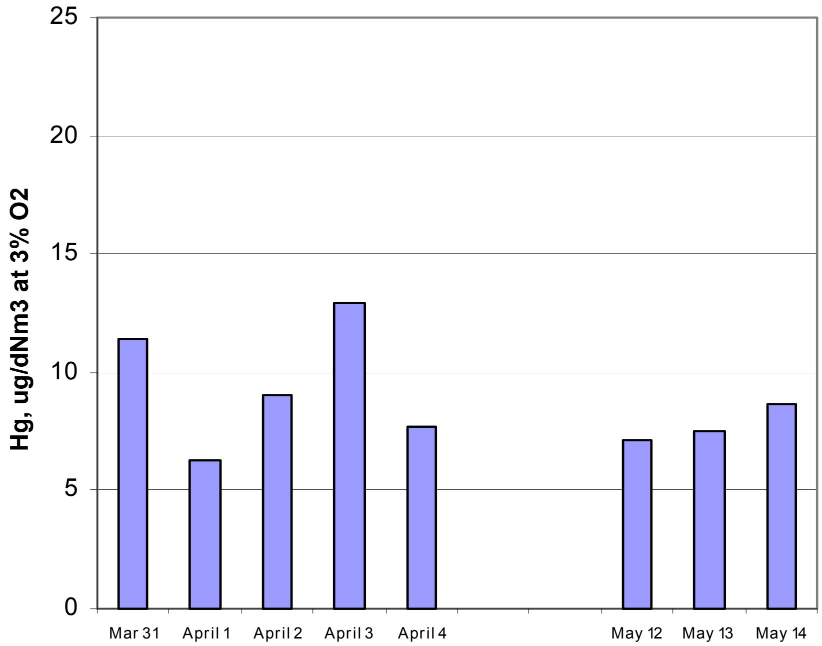

Figure 2. Coal mercury, in terms of µg/dnm^{3}at 3% O_2 for 2003 samples.

Table 2 gives the mercury and LOI contents of ash samples collected in April and May 2003. Figure 3 compares the LOI of these samples to the samples taken in 2001. The LOI values of the ash from the hot-side ESP and from the A-side of the baghouse are similar in 2001 and 2003. The LOI values of the B-side ash are higher in 2001, reflecting a higher rate of PAC injection than the May 2003 B-side sample. The relationship between LOI and mercury contest of the ash (Figure 4) seems similar. The mercury content of the hot-side ESP ash is generally lower in 2003 as compared to 2001.

Table 2. Mercury and LOI of ash samples from April and May, 2003.

ADA-ES #	MTI #	Sampled	Description	Hg, μg/g	LOI, wt%
GAS00203	03-190	4/2/2003	B-side BH	5.38	17.8
GAS00204	03-191	4/2/2003	HESP	0.334	13.6
GAS00205	03-192	4/2/2003	A-side BH	0.241	10.8
GAS00208	03-195	4/3/2003	B-side BH	6.4	21.4
GAS00265	03-199	5/14/2003	A-side BH	0.894	16.5
GAS00266	03-200	5/14/2003	B-side BH	7.61	16.9
GAS00267	03-201	5/14/2003	HESP	0.53	13.7

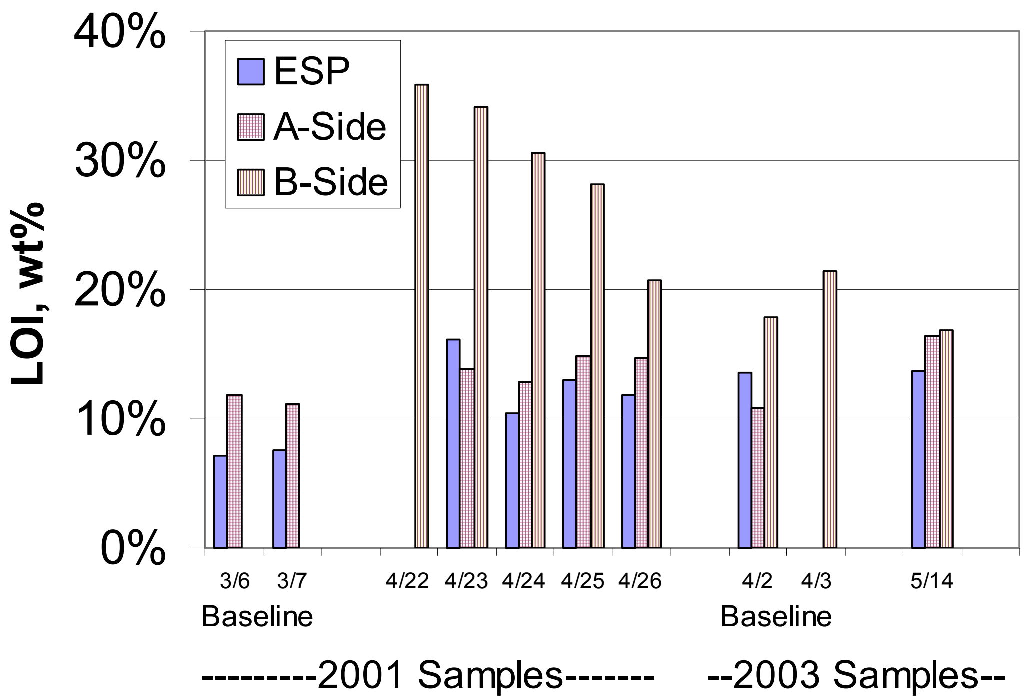

Figure 3. Comparison of LOI of Gaston Ash between 2001 and 2003.

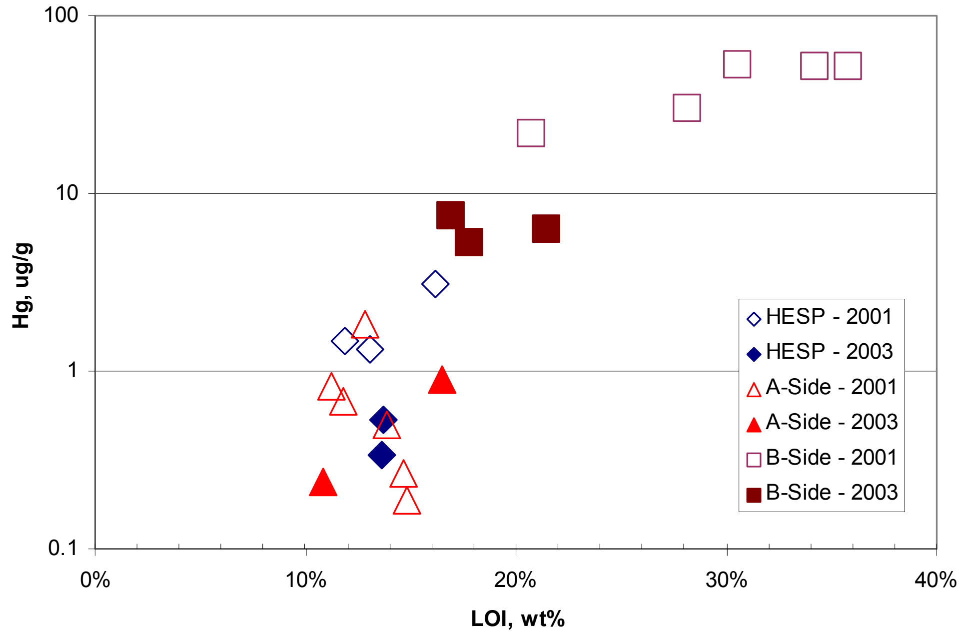

Figure 4. Mercury content of ash as a function of LOI.

To see if there is any correlation between LOI in the ESP ash and A-side ash, I looked at the hot foil LOI measurements made July-September 2003. Figure 5 shows no correlation between LOI in the ESP and in the A-side of the baghouse.

In Figure 6, all the hot foil data are plotted and compared with the LOI values for April and May 2003. During July and August, the LOI of the ESP ash varied from 7% up to 15%. A-side ash had an average LOI of about 15%, but there were excursions to more than 20%. As Figure 5 demonstrated, these excursions were not necessarily related to high LOI in the ESP. However, there may be some issues with timing of the samples and the emptying of hoppers. Without more information, I can't speculate any further.

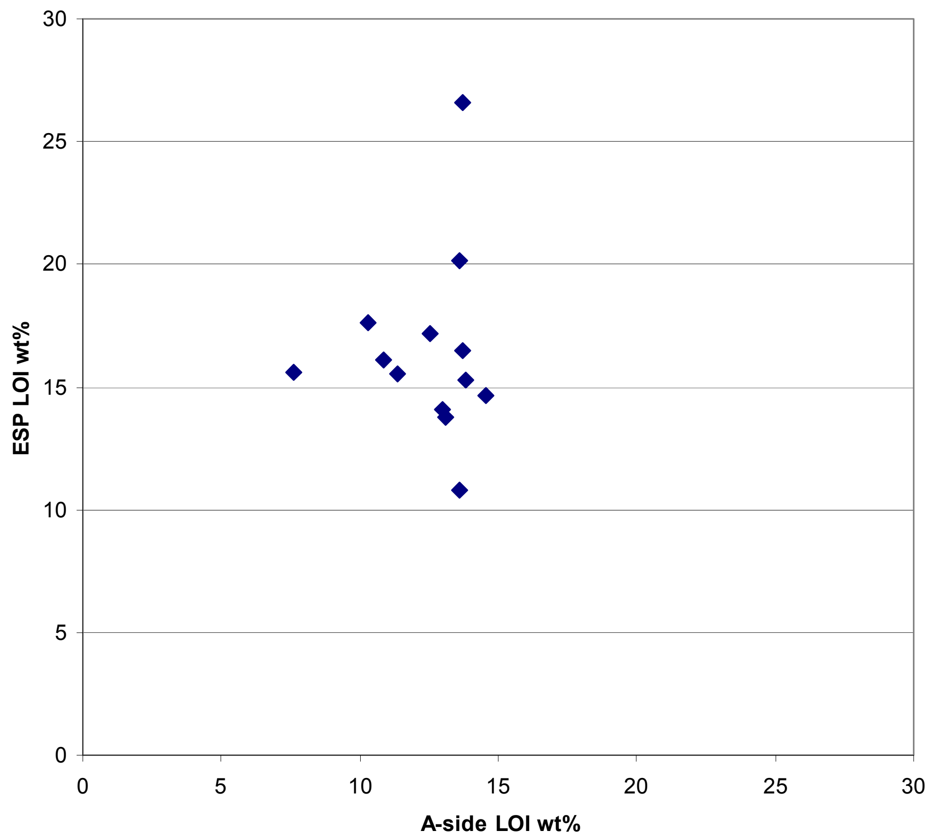

Figure 5. LOI in A-side ash as a function of LOI in ESP ash, July-August, 2003; LOI measured with hot foil technique.

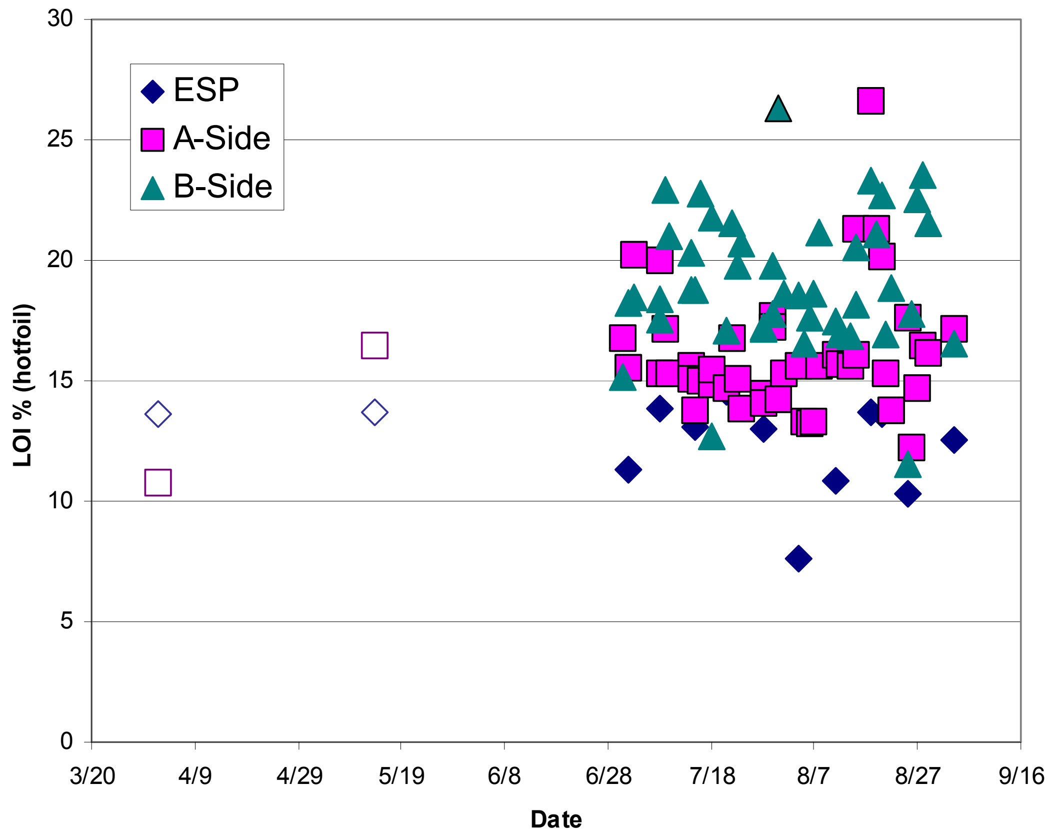

Figure 6. LOI measured by hot foil technique, July-August 2003.